12.—A fossil bone deposit near Perth, Western Australia, interpreted as a carnivore's den after feeding tests on living Sarcophilus (Marsupialia, Dasyuridae).

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Abstract

Carcases of marsupials have been fed to living specimens of the Tasmanian Devil (*Sarcophilus harrisi*), and the bony content of these carcases has been recovered. The kinds of damage inflicted by *Sarcophilus* on bone have been compared with damaged bone from an old cave deposit near Wanneroo, in the vicinity of Perth, Western Australia. This deposit contains remains of *Sarcophilus*, and it is concluded that the deposit represents the den or feeding place of *Sarcophilus*, probably of late Quaternary age.

Introduction

In 1964 we found a bone-bearing deposit in abandoned limestone quarries near Wanneroo, north of Perth, and in 1965 collected systematically from this deposit. Most of the bone in the deposit was in the form of small fragments, but among the larger identifiable fragments were some attributable to *Sarcophilus*. *Sarcophilus* still survives in Tasmania, where it is known as the "devil"; it is carnivorous. The association of fragmented bones with identifiable *Sarcophilus* remains suggested that our Wanneroo deposit represented a den or feeding place of *Sarcophilus*, and this suggestion received support from the feeding tests on living *Sarcophilus* specimens and from the other observations reported below.

Feeding tests on living Sarcophilus

Two young specimens of *Sarcophilus*, a male and a female, were obtained from Tasmania in 1965 by the Western Australian Museum. By kind permission of Mr. J. A. W. Kirsch, one of us (A.M.D.) was able to feed these animals with selected carcases under controlled conditions and study the resulting bony rejectamenta.

The feeding tests were conducted in June and July 1965. The animals were fed meat containing no bone (e.g. bullock hearts) for 3 days and then presented with 2 intact carcases of *Trichosurus vulpecula* (the brush-tailed possum) which had been freshly trapped and killed. These carcases were eaten over a period of 3 days, after which all faeces and unconsumed portions of the carcases were collected. The *Sarcophilus* specimens were then presented with 2 further *Trichosurus* carcases, which were left in the cage for 2 days. The cage was then cleaned out thoroughly, the animals were fed meat containing no bone, and their faeces were examined until it was clear (after 3 days) that no *Trichosurus* bone or fur remained in their intestines.

They were then presented with the carcases of 2 short-nosed bandicoots (*Isoodon obesulus*); these were largely ignored, and very little had been eaten after 4 days, one remaining quite intact. Unconsumed carcase material was collected, and the "devils" were placed on a bone-free diet until they ceased to pass bone or fur (after 2 days.) They were then presented with part of a carcase of a western grey kangaroo (*Macropus giganteus*—for nomenclature see Ride 1963) from which the skin, one fore-leg, one hind-leg and much of the remaining flesh had been removed. Only the uneaten bony material, not the faeces, was collected in this case also.

Observations on the feeding habits of these two *Sarcophilus* specimens, together with details of experimental procedures with the animals and with their bony rejectamenta have been recorded in a report by A. M. Douglas which has been lodged in the library of the Western Australian Museum.

Some of the *Sarcophilus* faeces containing *Trichosurus* fur and bone were treated with chlorocresol, dried in an oven, and preserved intact (W.A.M. specimen 65.11.1). The very fine bone fragments (65.11.3) were isolated from all the remaining faeces which were recovered. Some of the faeces so treated, consisting mainly of matted fur but still containing larger fragments of bone, were dried and have been preserved (65.11.2). The remaining faeces were hand-picked to remove the larger fragments of bone, and this bony material (65.11.4) was retained.

The uneaten *Trichosurus* fragments were cleaned of all flesh with the exception of one fore-leg (65.11.5) from one of the first pair of *Trichosurus* carcases. The cleaned bony rejectamenta from the first 2 *Trichosurus* carcases have been catalogued as 65.11.6 and 65.11.7; the rejectamenta from the second 2 *Trichosurus* carcases, also cleaned, have been catalogued as 65.11.8 and 65.11.9. The uneaten portions of the one *Isoodon* carcase which was attacked have been cleaned and retained as specimen 65.11.10. The uneaten portions of the partial *Macropus* carcase have been cleaned and retained as 65.11.11.

The specimens quoted above resulting from these feeding tests on living *Sarcophilus* have been compared with the fossil material from Wanneroo.

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The Wanneroo Sarcophilus den

The suspected *Sarcophilus* den is in Dunstan's Lime Kiln Quarries, an extensive series of quarries, now abandoned, about 9 miles north of the township of Wanneroo, and about 24 miles north of the central city area of Perth, Western Australia. These quarries cut into the extensive rock formation informally known as the "Coastal Limestone". One of the quarry roads runs alongside a low quarry face partly composed of a coarse calcareous breccia which we interpret as an old cave fill or floor deposit. The mass of breccia exposed above the roadway is about 60 feet long, and rises from road level in the west to a height of about 10 feet in the east; several parts of the mass contain bone fragments. The breccia carries a capping of calcareous aeolian dune rock typical of the "Coastal Limestone". We interpret this capping as the remnant of a cave roof which formerly was more extensive, but which has been reduced by natural processes to a thickness of only a few feet. The whole mass is surmounted by a soil carrying a plant cover. Quarrying or road-making operations have produced a vertical section of depth about 12 feet in this composite system of soil, aeolianite and breccia.

About central in the vertical section is a cavity with opening about 9 feet wide and about 3 feet high, penetrating about 10 feet into the rock mass. This cavity appears to be the remnant of a formerly more extensive cave which had been partly filled by a tumbled mass of rock fragments and more finely divided material now represented by the breccia. The lower parts of the cavity as it now exists are defined by bone-bearing breccia, the roof by dune rock.

The breccia so far described is a well cemented and coherent rock, and its bone content is fragile, so that it is difficult to recover identifiable specimens from it. However, there is an unconsolidated deposit in the floor of the cavity, and this unconsolidated deposit is rich in bone fragments which are easily recoverable by sieving. We have examined a little fossil material from the consolidated breccia, and a larger

Figure 1.—Comparison of damage inflicted by living *Sarcophilus* on modern bone with damaged bone from Wanneroo fossil deposit. In each group or pair of specimens (a-i) the fossil bone is darker than the modern, and the fossil specimen or specimens are placed immediately below their modern counterparts. a.—bone chips of generally similar size; b.—roughly circular punctures; c.—mandibular rami complete in front, but with rear ends irregularly fractured; d and e.—irregular embayments part way along bones; f and h.—similarly fractured ends in bones of similar size; g.—fractures incompletely separating chips from shafts of bones; i.—fractures in bones of such size that carnivores smaller than *Sarcophilus* can hardly have been responsible.

quantity obtained by systematic sieving of portion of the unconsolidated floor deposit. It is probable that this unconsolidated deposit contains bone specimens derived from the consolidated breccia by weathering, and it may contain bone of more recent origin.

The consolidated breccia has yielded fragments of *Sarcophilus* (65.10.194), of *Petrogale* (65.10.201, 65.10.202?) and of other phalangerids, not specifically identifiable but of medium size (65.10.203-205). The unconsolidated floor deposit has yielded *Sarcophilus* (65.10.191-193, 65.10.195), *Dasyurus* (65.10.174-176), *Petrogale* (65.10.162-170, 65.10.188-190, 65.10.196-197), *Bettongia penicillata* (65.10.177), *Bettongia lesueuri* (65.10.178-187), some other macropods of medium size (65.10.198-199), a large macropod (65.10.172, 64.1.10), *Isoodon* (65.10.161) and a murid (64.1.11). Of these mammals the rock wallabies (*Petrogale* sp.) and the rat kangaroos (*Bettongia lesueuri*) are most abundant. Among the non-mammalian fossils in the unconsolidated floor deposit we have recognized *Varanus* (65.10.159) and other lizards (65.10.160), the snails *Bothriembryon* (65.1168), *Luinodiscus* (65.1177) and *Austrosuccinea* (*sensu* Iredale) (64.1) and the mussel *Westralunio* (64.2). Presumably the mussel was transported by some scavenging or predatory animal, perhaps by man.

Comparison of modern with Wanneroo bone samples, and discussion

We have not attempted to estimate proportions of bone fragments of given size ranges in the modern and fossil samples because we believe the conditions under which the samples were produced probably were different. Under natural conditions, *Sarcophilus* might drag smaller carcases back into a den to feed upon, whereas it might attack large carcases only in the field. In a den, *Sarcophilus* might be expected to chew carcases thoroughly, whereas uneaten portions of carcases were removed from our modern caged animals every few days. Possibly, an animal under natural conditions might avoid defaecating in its den, so that the den deposit would come to contain only a small portion of the most finely divided bone.

Our comparisons therefore have included only rough estimates of relative proportions of bone fragments of different sizes in our two samples, and have centred upon the nature of fractures, punctures and incisions in the samples. Close similarities between the two samples are observable: see Figure 1. In this Figure the specimens have been arranged in pairs, with a piece (or pieces) of bone attacked by the modern animals above in each pair, and a (darker) piece from the Wanneroo deposit below. In each pair of specimens, the kind of damage visible on the modern specimen appears to be similar to that on the fossil specimen. We have noted no kind of damage in the modern sample which cannot be matched from the fossil sample, and vice versa.

It is to be expected in a cave deposit that some of the bony content would have been crushed or broken by blocks of rock falling from the roof, and it might not always be possible to decide whether a given fracture in a piece of bone resulted from tooth action or falling rock. However, certain kinds of damage, such as more or less circular punctures or rather frayed embayments part way along pieces of bone, appear to be much more readily explained as tooth action than as falling rock action.

Sarcophilus is not the only carnivore which could be envisaged as accumulating the bones found at Wanneroo; *Thylacoleo*, *Thylacinus*, or *Canis* might be involved. Smaller carnivores such as *Macroderma*, owls, *Phascogale* or even *Dasyurus* might be expected to accumulate a far greater proportion of small mammal and other small vertebrate prey. Lizards, rodents and other small animals are poorly represented in the Wanneroo deposit, rock wallabies and rat kangaroos predominating. Thus, although the deposit contains the remains of *Dasyurus* as well as of *Sarcophilus*, the latter is more likely to have accumulated most of the bone in the deposit.

Marks on Australian fossil bones have been interpreted as damage inflicted by the teeth of carnivores by several writers, notably by Spencer and Walcott (1912) in their discussion of the food habits of *Thylacoleo*. But it has not been suggested that any particular kind of damage indicates any particular carnivorous species, and we have noticed no kind of damage that might reasonably denote *Sarcophilus* rather than any other carnivore. *Sarcophilus* is the only one of the larger carnivores so far recognized in the Wanneroo deposit. Thus it is reasonable to postulate that *Sarcophilus* may have been responsible for most of the bony content of the deposit. Accumulations of bone in Western Australian localities have been ascribed by Lundelius (1960 and 1963) to *Sarcophilus* because of the association of much-fragmented bones of medium-sized animals with *Sarcophilus* remains in the same deposit.

The "Coastal Limestone" enclosing the Wanneroo deposit is of Quaternary age (Smith 1963). Consequently the deposit itself is probably of late Quaternary age, but we are not at present able to estimate this age more precisely.

Acknowledgements

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Royal Society Medallist 1966

C. F. H. Jenkins

Clee Francis Howard Jenkins, the tenth recipient of the Society's Medal awarded for distinguished work in science connected with Western Australia, was born in Adelaide in 1908. He received his education at St. Peter's College, Adelaide, and graduated as Bachelor of Arts in the School of Science of the University of Western Australia in 1935. In 1939 he received his Master's degree. After joining the staff of the Western Australian Museum as a cadet in 1929 he was appointed to the Western Australian Department of Agriculture as an entomologist in 1933, and as Government Entomologist in 1939. In 1964 he was appointed Chief of the Department's Division of Biological Services, incorporating Entomology, Botany, Plant Pathology and Weeds and Seeds, a position which he continues to hold.

Mr. Jenkins receives the Society's Medal jointly for his exceptional service to the Society, a primary purpose of which is the advancement of science in all its branches, and for his personal achievements in his own field.

He first joined the Society in 1929 and began active work for it with his election as Assistant Librarian. Since then he has served in Executive or Council positions for 31 years as follows—Hon. Secretary for 10 years, Vice-President for 4 years, President for 2 years, and a Member of Council for 15 years, in which position his service continues. His two terms in the Presidential chair were separated by 18 years. In addition he has been a member of a number of Council Committees, including Chairman of the important Standing Committee on Conservation.

His work with the Department of Agriculture has been mainly in the field of insect control, for which he has been responsible since 1939. The importance of such studies to the agricultural industry of the State can hardly be overemphasized.

His early work on grasshopper control contributed to the present low incidence of this pest. Later he advised on the control of insect pests at military camps and carried out a survey of insects that bite rabbits, for the spreading of myxomatosis. His sound recommendations for eradication are responsible for the absence from Western Australia of such important pests as codling moth, oriental fruit moth, and sirex wasp, as well as for the reduction of fruit fly to its present low level. Probably the best known of his projects is that of argentine ant control, the cost of which has reached approximately $1,500,000 and which has involved the treatment of 40,000 acres of infestation. At the Department of Agriculture he has maintained and increased a collection of insects which now number about 100,000, including many type specimens.

Mr. Jenkins has also made a distinguished contribution to science by his enthusiastic encouragement of natural history, and in particular ornithology. He has been closely associated with the Australasian Ornithologists' Union, the Western Australian Naturalists' Club, the Western Australian Aviculture Society and the Western Australian Gould League. In 1963 his advice was sought when H.R.H. The Duke of Edinburgh expressed a preference for bird-watching to the more conventional occupations of royal visitors. He maintained a weekly newspaper column on natural history for many years, and still continues the similar radio talks he has made for the last 15 years, in addition to frequent other broadcast and television presentations. His ability has been recognised by deputy presidency of both the National Parks Board of Western Australia and the Zoological Gardens Board. He is also a Council member of the National Trust, the newly formed Australian Conservation Foundation, and Vice-Chairman of the Western Australian Division of A.N.Z.A.A.S.

Erratum

A new species of Nectria (Asteroidea, Goniasteridae) from Western Australia, by S. A. Shepherd and E. P. Hodgkin; Volume 48, Part 4, Paper 11 of the Journal.

Mr. Shepherd's name was misspelt "Sheperd" in the published Journal. The error was corrected in the reprints, with a footnote drawing attention to the change.